

CALCULATION OF DOSE DEPOSITION IN 3D VOXELS BY HEAVY IONS

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The biological response to high-LET radiation is very different from low-LET radiation, and can be partly attributed to the energy deposition by the radiation [1]. Several experiments, notably detection of γ -H2AX foci by immunofluorescence, has revealed important differences in the nature and in the spatial distribution of double-strand breaks (DSB) induced by low- and high-LET radiations [2,3]. Many calculations, most of which are based on amorphous track models with radial dose, have been combined with chromosome models to calculate the number and distribution of DSB within nuclei [4] and chromosome aberrations [1]. In this work, the Monte-Carlo track structure simulation code RITRACKS [5] have been used to calculate directly the energy deposition in voxels (3D pixels). A cubic volume of 5 μm of side was irradiated by 1) 450 $^1\text{H}^+$ ions of 300 MeV (LET ~ 0.3 keV/ μm) and 2) by 1 $^{56}\text{Fe}^{26+}$ ion of 1 GeV/amu (LET ~ 150 keV/ μm). In both cases, the dose deposited in the volume is ~ 1 Gy. All energy deposition events are recorded and dose is calculated in voxels of 20 μm of side. The voxels are then visualized in 3D by using a color scale to represent the intensity of the dose in a voxel. This simple approach has revealed several important points which may help understand experimental observations. In both simulations, voxels which receive low dose are the most numerous, and those corresponding to electron track ends received a dose which is in the higher range. The dose voxels are distributed randomly and scattered uniformly within the volume irradiated by low-LET radiation. The distribution of the voxels shows major differences for the $^{56}\text{Fe}^{26+}$ ion. The track structure can still be seen, and voxels with much higher dose are found in the region corresponding to the track "core". These high-dose voxels are not found in the low-LET irradiation simulation and may be responsible for DSB that are more difficult to repair. By applying a threshold on the dose visualization, voxels corresponding to electron track ends are evidenced and the spatial distribution of voxels is very similar to the distribution of DSB observed in γ -H2AX experiments, even if no chromosomes have been included in the simulation. Furthermore, this work has shown that a significant dose is deposited in voxels corresponding to electron track ends. Since some δ -rays from iron ion can travel several millimeters, they may also be of radiobiological importance.

References

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